Progress of Electro-Hydraulic Scabbling Technology for Concrete Decontamination

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Introduction

Concrete decontamination from organic substances, hazardous metals, and, especially, radionuclides, which may deeply penetrate the concrete, requires removal of up to one inch of concrete surface layer. Several methods, some of which are extensions of conventional surface treatment processes, were suggested]) for deep concrete scabbling; e.g., the use of jackhammers or explosives, mechanical dry scabbling/scarification, shot blasting, microwave spalling. Each of these methods has inherent problems: the generation of contaminated dust or rubble, not readily adaptable to remote control, cost, etc.

The Electro-Hydraulic Scabbling (EHS) technique has been developed b Textron Systems Division (TSD) within a three-phase DOE-sponsored research program.(,3) After the Phase I feasibility study, a prototype 8 kW EHS unit was designed and assembled in Phase II. This system was tested initially by scabbling noncontaminated concrete at the TSD site, and later at the DOE Fernald site where a concrete floor containing uranium was decontaminated. At the Fernald test, the unit operated as expected without problems and reduced the counts per minute of the scabbled area by more than 90%. Currently in Phase 111, a larger 30 kW unit has been assembled and prepared for more extensive testing and demonstration.

EHS Basics

The EH effect involves several interrelated electrical, mechanical flow and optical phenomena accompanying high voltage (tens kV) breakdown and short (a few µsec), high current (tens kA) spark-like discharges through water. The discharges result in the formation and expansion of a plasma bubble and consequent propagation of shock waves and turbulent water streams. This results in the deformation, cracking, crushing, etc. of bordering solids, Specifically, for concrete scabbling, a series of breakdowns at a few pulses per second repetition rate is organized between rod- or strip-shaped electrodes positioned with a minimum clearance of the concrete surface (e.g., floor) under a thin layer of water. The water not only serves as a transfer medium for shock and cavitation waves, but also prevents useless air breakdown above the concrete surface. Spalling, crushing, and grinding of concrete results in the formation of cavities/craters with depth and volume, depending on the strength of concrete, energy input per pulse, electrode geometry, as well as other factors. TSD-site trials showed that from ().()3 to 0.12 $in.^3$ of concrete can be removed by a single 1kJ pulse, which is equivalent to energy consumption of 4 to 16 kWh per 1 $ft.^3$ of concrete, or 0.08 to 0.32 kWh per 1 $ft.^2$ of concrete surface scabbled to 1/4” depth, To proceed with a single-pass area processing of concrete floor, 1‘ to 2.5’ wide parallel strip

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electrodes are used in the TSD-designed scabblers. Scabbling depth is controlled by the selection of the pulse energy, pulse frequency, and a number of pulses per unit electrode width and unit length in a direction of electrode traverse over the floor surface.

Scabbling Decontamination Trials at DOE Fernald Site

operation of a first EHS prototype unit (see description in Refs. 2, 3) was demonstrated at FEMP (Fernald Environmental Management Project) in September 1995. The test program had two main objectives:

- To demonstrate the technical feasibility of concrete floor scabbling from 1/4”- 1/2” depth, to obtain its performance parameters, and to prove reliability of the unit.

- To confirm that removal of a surface concrete layer by wet scabbling results in significant reduction of radioactivity and uranium concentration.

The experiments were conducted in the Metal Fabrication Plant (Bldg. 6) at the floor areas with fixed contamination (mostly trapped uranium particulate) at average 1200 b/g cpm and 2800 ppm U (measured by x-ray fluoroscope) and maximum levels about 8000 cpm and 9000 cpm, respectively, A total of 35 $ft.^2$ of concrete was scabbled.

Scabbling Data. Equipment used in these trials is shown in operation in Figure 1. It includes HV power supply cabinet (1), process control cabinet (2), scabbling chamber/enclosure (3) containing a scabbling module with 26” wide electrodes and module positioner, water/fine debris flow system (pump valves, drum/collector (4)), HEPA vacuums (5) to reduce enclosure air pressure, and (6) to remove (manually in these experiments) wet coarse rubble remaining on the flow after enclosure is transferred to the next position. The scabbling chamber and flow system were mounted on a conventional forklift truck (7). Equipment operated problem free, without breakdowns or component replacements. The main characteristics of the equipment and operation are shown in Table 1,

Appearance of the after-scabbling concrete surface is illustrated by photo (Figure 2). The inhomogeneous structure of concrete with alternative hard components (gravel, “expelled” from the structure by shock waves largely intact, and soft matrix-sand/cement mix) disintegrated and ground by cavitation accounts for the presence of local cavities and the fluctuation of scabbling depth. More systematic and larger-scale scabbling depth changes revealed by surface profiling (laser Geodimeter measurements made by the FEMP team - see example in Figure 3) can be explained by a combination of still rather simplistic electrode positioning and by the concrete surface defects.

Decontamination Data. Data in Tables 2 and 3 indicate that on average more than 10 times reduction of the radioactivity and of the uranium concentration has been achieved by EHS. The reduction is much higher where concrete had local defects with high initial contamination. At least part of the residual radioactivity should be attributed to minor amounts (about 10 $g/ft.^2$) of fines remaining over uneven surface after wet rubble removal. If a 100-300 residual radioactivity level is still of concern, an improved wet or dry post-scabbling processing should be implemented,

Distribution of contaminants in various waste components - filtered and unfiltered liquid (L(F) and L(U)), wet solid debris (S), and dust (D) - is shown in Figure 4 where water and debris circulation are schematized and sampling locations are shown, The content of uranium in the solid debris is about the same as measured over the unscabbled concrete surface. All contaminant is removed by return water filtration, indicating that it is not water-soluble; this allows reuse of water through many processing cycles, substantially reducing the amount of liquid waste.

More details of these tests are included in the TSD Phase 11 Topical Report[2] and in the FEMP Field Assessment/Data Package Report.[4]

Development of an Industrial EHS System

The design, assembly, testing, and demonstration of a higher power/higher scabbling rate and a more user-friendly operational unit with improved debris removal capability is an objective of the current Phase 111 of the project. The unit (see Figure 5a, b) is assembled and its shakedown testing at the TSD facility is in progress. Its main operating parameters, projected performance, and rough estimates of capital and operating costs are given in Table 4. Field testing/demonstration of this unit is anticipated to begin in early 1997.

It is expected that an industrial unit appropriate for medium scale scabbling tasks would have about two times higher power (60 kW), would operate at higher levels of automation, and provide a 60 to 120 $ft.^2/hr.$ effective scabbling rote, depending on the depth. According to available literature, for instance,[1] this decontamination rate is similar or better than the rates achieved by dry scabbling or shot blasting. Among the advantages of the EHS technique are the ability to perform single-pass deep scabbling and convenient scabbling depth control, which can be guided by a built-in real-time sensor of remaining contamination. Other features are the absence of airborne dust or other safety/environment defecting factors and the amount of rubble requiring controlled disposal.

Optional designs are under development. The first one is based on electric power supply generating 120 kV pulses breaking down directly through the concrete surface layer, while the second has a much smaller size scabbling module. This smaller unit would allow continuous scabbling/traverse/debris removal, and add capabilities for scabbling vertical surfaces, local areas around obstacles, and at deep local concrete surface defects.

Acknowledgments

Textron Systems Division (TSD) wishes to acknowledge the technical and administrative collaboration and support of the FERMCO staff at the DOE Fernald facility. The cooperative interaction that began with the initial arrangements for the tests, the performance of the test program, and the prompt provision of test analysis were eminently important to the success of the program, In particular, TSD wishes to acknowledge the efforts of Dick Martineit, Ken Geiger, and Kathy Adams in making the tests a success as well as a satisfying experience

TSD also wishes to acknowledge the managerial and technical contributions of METC CORS Mary Beth Ashbaugh, Kelly Pearce, James Longanbach, and the recently appointed John Duda. Their direction and suggestions have been most valuable.

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2. Goldfarb, V., Concrete Decontamination by Electro-Hydraulic Scabbling (EHS), DOE/METC Contract No. DE-AC21-93 MC30164, Topical Report, Phase II, March 1996.

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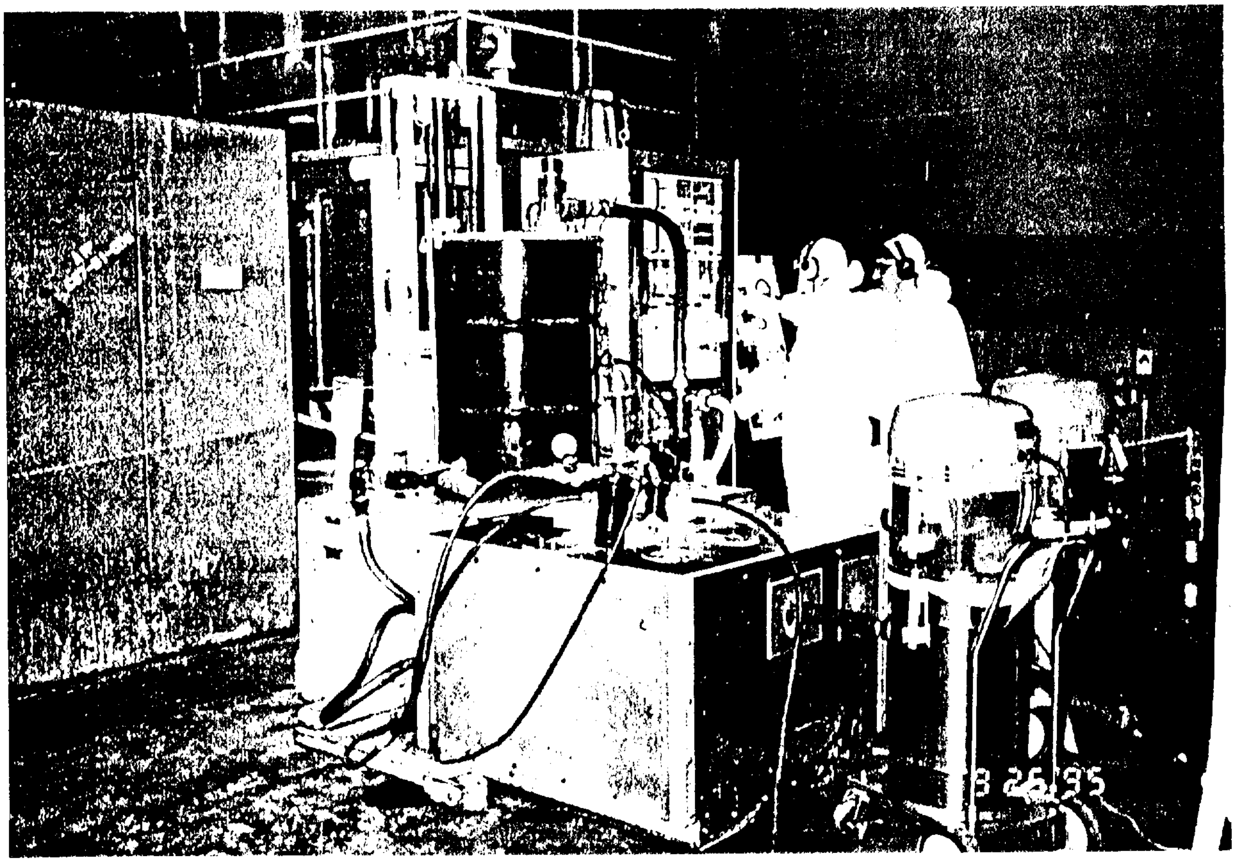

Figure 1 EHS Equipment in Operation at Fernald Site (FEMP photo)

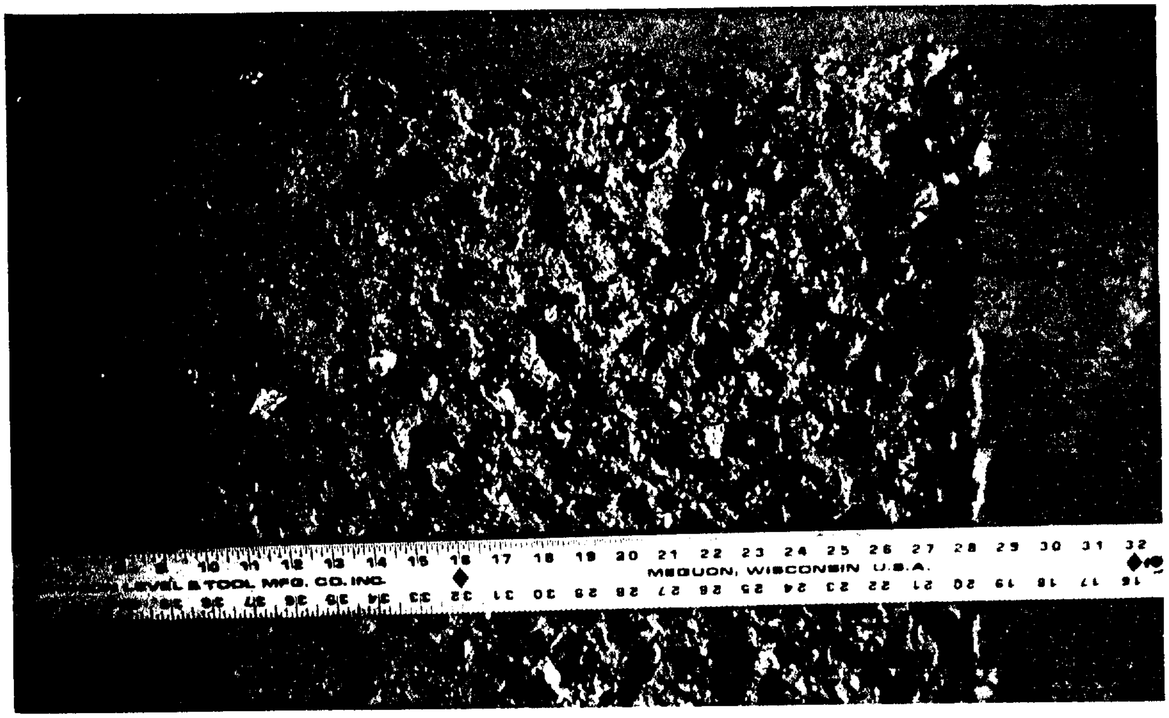

Figure 2 Appearance of EH Scabbled Concrete Surface. Oblique illumination used **to** increase contrast. Concrete floor at TSD site, scabbling depth 1/2".

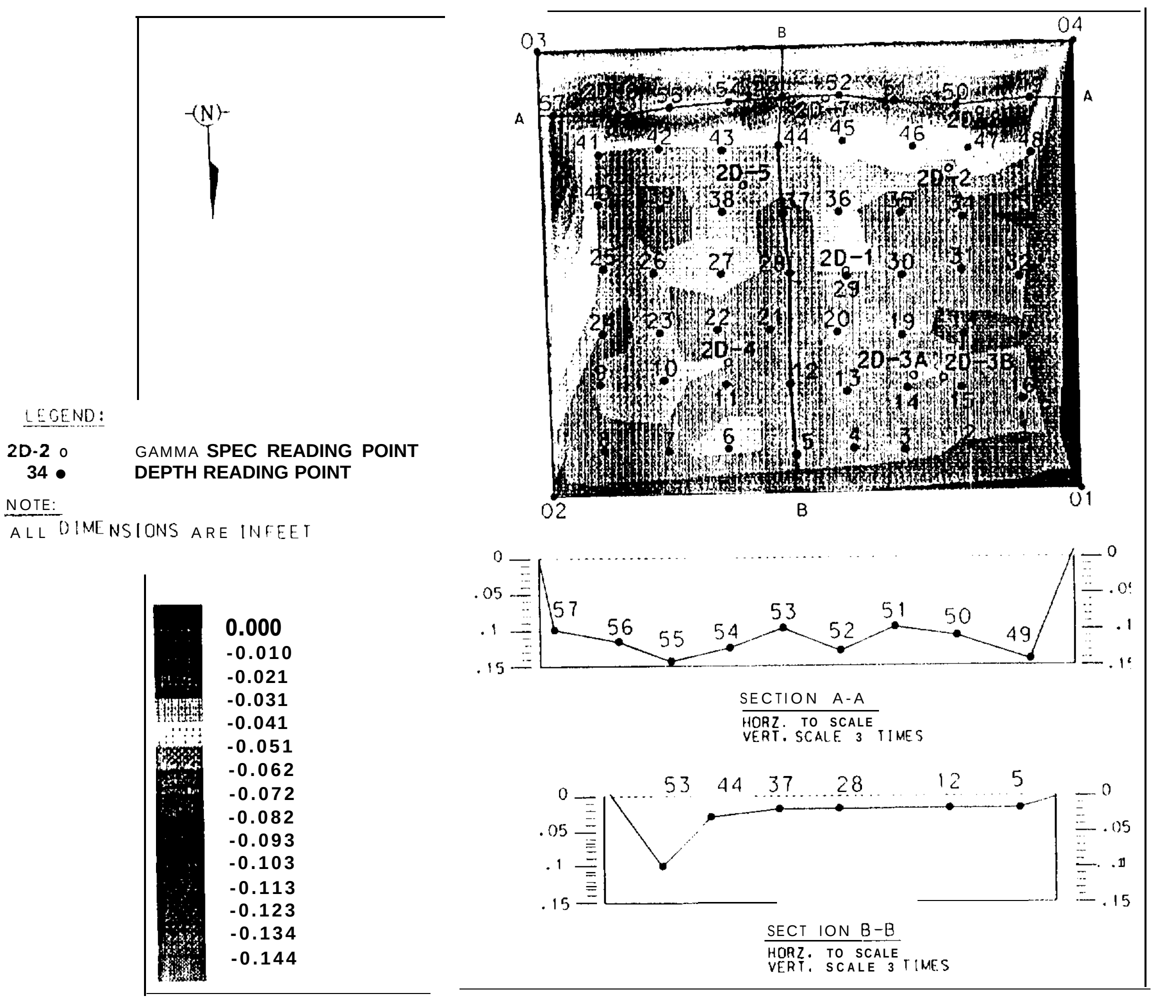

Figure 3 Topographical Map and Scabbling Depth Profiles for One of the Decontaminated Floor Segments at Fernald (FEMP Geodimeter data)

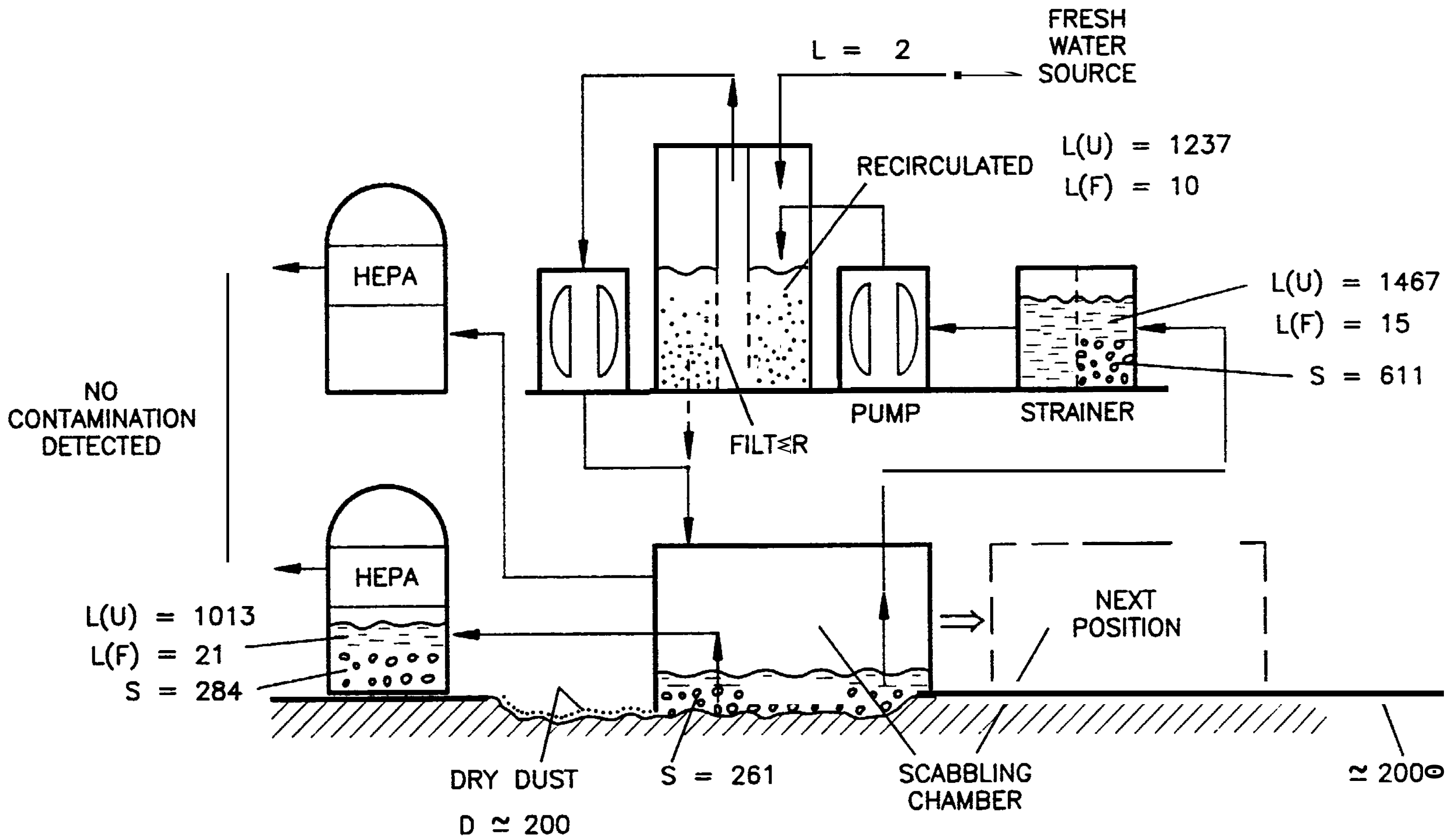

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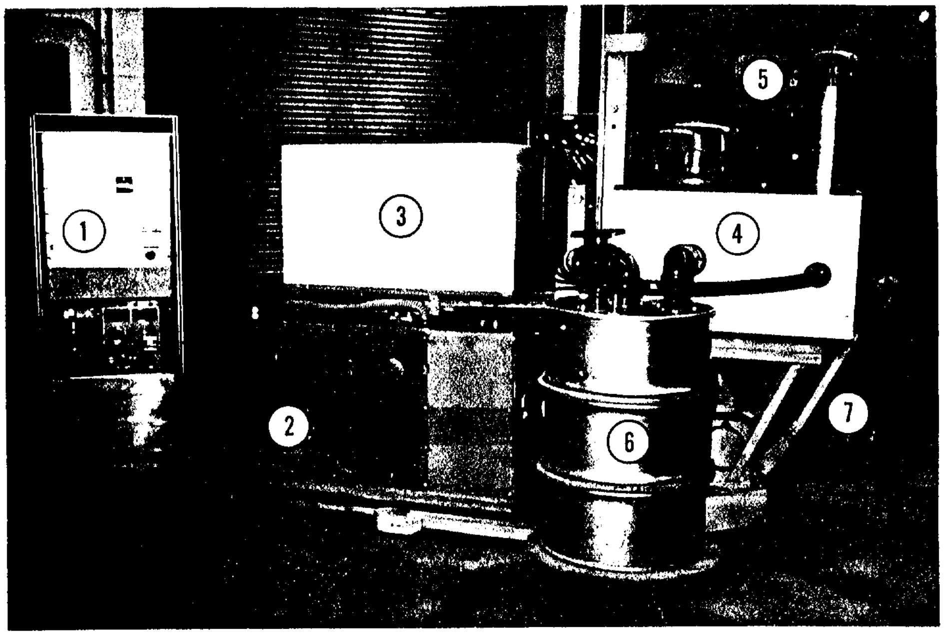
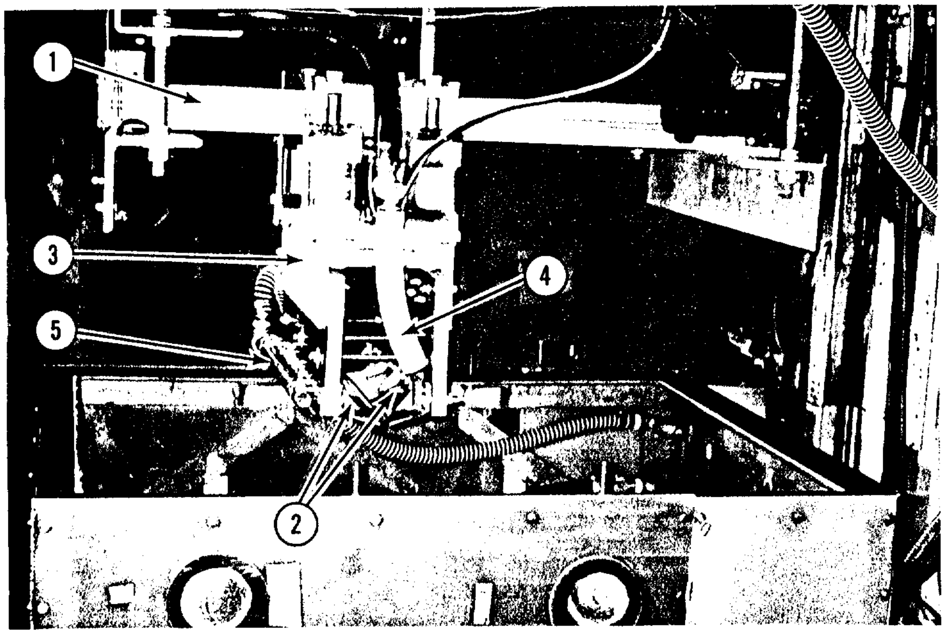
Figure 4 Schematic of Process Water and Solid Waste Sampling. Uranium content data (in ppm, by FEMP) are shown for one of the floor segments.



a)



b)

Figure 5 Phase 111 ("Industrial Prototype") EHS Unit

a) General view:

1- HV power supply and electric controls
2 - Scabbling chamber/water enclosure
3- Electric pulse forming network (enclosed)
4- Air/water/debris flow system (enclosed)
5- Vacuum power heads
6 - Debris separating/collecting drum (replaceable. except cover)
7- Electric forklift truck (conventional, electric)

b) Scabbling module lifted over enclosure

1 - Positioner with motor drive
2 . Electrodes
3- Electrode support frame
4 - 1-IV cables
5- Water jets manifold

Table 1. Main Operating and Performance Parameters for
Phase II EHS System

Electric Power (nominal AC) (actual average)	4 or 8 kW (two parallel supplies) 2 or 4 kW
Pulse Frequency	1.4 or 2.3 Hz
Operating Voltage	15 to 19 kV
Scabbling Rate (net, scabbling) (effective, incl. traverse and clean)	 4.9 to 5.7 ft.^{2}/hr. -4 ft.^{2}/hr.
Scabbling Depth (area weighted)	0.24” (0.14” to 0.32”)
Amount of Rubble Collected	28 kg

Table 2. **Pre-** and **Post-Scabbling** Radioactivity Readings
Averaged Over Floor Segments, Taken by TSD

Floor Segment Designation	Average Radioactivity, CPM		CPM Ratio
	Pre-Scabbling	Post-Scabbling	
B	370	26	14.2
c	1130	19	59.0
D	3060	210	15.5
F	1280	280	4.6
G	450	122	3.7
H	860	78	11.0
I	1240	25	49.0

Table 3. **Pre-** and **Post-Scabbling** XRF Data Averaged Over Floor Segments

Floor Segment Designation	Average Uranium Content, PPM		PPM Ratio
	Pre-Scabbling	Post-Scabbling	
A	846	133	6.4
B	2570	652	3.9
c	1210	158	7.6
D	2090	61	34.0
F	2280	310	7.4
G	5770	191	30.0
H	5090	407	12.4

Table 4. Main Operating Parameters and Projected Performance/ Cost Data for an Industrial Prototype Unit (Phase III)

Unit Size (without truck)	8' x 4' x5'
Unit Weight	1700 lbs.
Power (AC installed)	30 kW
Operating Voltage	28-32 kV
Pulse Energy	3-5 kJ
Pulse Frequency	4-7 Hz
Electrode/Scabbled Track Width	30"
Area Scabbled at Each Chamber Position	6 ft.^{2}
Scabbling Depth	1/4" to 1"
Scabbling Rate at 3/8" Depth: net effective, incl. clean	 45 ft.^{2}/hr. 30 ft.^{2}/hr.
Unit (Equipment) Cost	$120,000
Operating Cost (Total) including: consumables maintenance capital (at 5 years) labor	5-1o $/ft.2 5% 12% 8% 75%